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GROUND WATER IN THE VERMILION RIVER BASIN, LOUISIANA

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GROUND WATER IN THE VERMILION RIVER BASIN, LOUISIANA[1,2,3]

Paul H. Jones[4]

ABSTRACT

The geology and hydrology of the thick sand-and-gravel aquifer that underlies the lower part of the Vermilion River basin favor recharge of its water supply from the river. When the river contains salty water the aquifer is recharged by water unfit for domestic use or for irrigation. Wells near the river yield salty water in the late fall and winter after the river has been intruded by water from Vermilion Bay. Because the aquifer extends throughout southwestern Louisiana and is tapped by more than a thousand rice-irrigation wells that have caused a westward hydraulic gradient from the Vermilion River, continued salt-water contamination from the river threatens the total ground-water supply of the southern part of southwestern Louisiana.

INTRODUCTION

The Vermilion River basin of southwestern Louisiana is underlain by a thick water-bearing formation that occurs throughout this part of the State and is tapped by more than a thousand rice-irrigation wells, many industrial and public-supply wells, and several thousand domestic wells. All municipal supplies in southwestern Louisiana draw upon this source.

The purpose of this paper is to describe and explain the relation between surface and underground water conditions in the lower Vermilion River basin. The importance of this relation cannot be overemphasized because the future availability of fresh ground-water supplies in the entire area of southwestern Louisiana will depend in large part upon the effectiveness with which salt-water intrusion in the Vermilion River basin is prevented.

The part of the basin discussed in this paper lies in south-central Louisiana (Fig. 1) between Milton, in southwestern Lafayette Parish,

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2. Publication authorized by the Director, U. S. Geological Survey.
3. Paper based on information obtained in investigations of the ground-water resources of Louisiana by the Geological Survey, United States Department of the Interior, in cooperation with the Louisiana Geological Survey, Department of Conservation, and the Louisiana Department of Public Works.
4. District Geologist, Ground Water Branch, U. S. Geological Survey.

and Vermilion Bay. Ground-water conditions along the Vermilion River for a distance of 5 or 6 miles on either side of the stream serve to demonstrate the relations we are to consider. The area is rectangular and is some 25 miles long, roughly paralleling the southerly course of the river. It lies at the southeastern margin of the rice-farming area (Fig. 2).

Geology

The geology of southwestern Louisiana, including the lower basin of the Vermilion River, is intimately related to the ancient courses of the Mississippi River. In fact, the origin of most of southern Louisiana during Pleistocene time (commonly called the Ice Age), as a result of deposition of vast quantities of glacial outwash consisting largely of gravel and sand, can be directly attributed to the Mississippi River and its distributaries (Howe et al., 1935, p. 4).[5] The principal aquifer, which extends as a continuous deposit of sand and gravel for more than 100 miles across southern Louisiana and as far north as central Rapides Parish—about 140 miles from the Gulf of Mexico—is overlain throughout most of southwestern Louisiana by a deposit of clay, silt, and marine shells. This material owes its origin in part to slack-water deposition in the back swamps during the later stages of alluviation by the Pleistocene Mississippi River, in part to coastal marsh and marine marginal deposition such as we know today along the Gulf shore line of Cameron and Vermilion Parishes, and in part to delta-fringe deposition similar to that near the mouth of the modern Mississippi River (Russell, 1939, pp. 153-177).

The fine-textured top stratum has low permeability and provides an excellent subsoil for rice farming, even where it is only a few feet thick. In all of southwestern Louisiana, however, there are only two extensive areas in which it is less than 100 feet thick. One of these is in the upper drainage basin of the Calcasieu River, and the other is along nearly the entire length of the Vermilion River.

From Lafayette, in Lafayette Parish, almost to Vermilion Bay the Vermilion River follows a Pleistocene Mississippi River meander belt, as shown on Figs. 2 and 3. The texture of meander-belt deposits is typically more coarse grained than that of the adjacent back-swamp areas, and although the clay masses in the meander belt are thick they have little lateral continuity.

Extensive study of the flood plain of the modern Mississippi River, as described by Fisk (1944), demonstrates that the meander belt of a major stream traversing a flood plain underlain by sand and gravel deposit becomes fixed in position between thick back-swamp clays; and the meandering of the stream thenceforth is confined to a relatively narrow belt, the deposits of which it reworks again and again. Wide variation in the stage of such a stream produces a sequence of scour and fill that effectively lifts coarse-grained deposits from the bottoms of scour pools and deposits them near the surface on the point bars

5. See references at end of text.

inside the bends. The effect is a thickening of the permeable beds throughout the width of the meander belt, as shown on Fig. 4. This profile is analogous to conditions along a geologic section transverse to the ancient meander belt followed by the Vermilion River.

The ancient meander belt was identified from physiographic evidence, chiefly as shown on aerial photographs. Records of many water wells and geophysical test borings along the Vermilion River furnish subsurface evidence of its presence. Where the belt of meanders is lost beneath the Recent marshland along the coast it appears that the Pleistocene aquifer might be exposed to recharge from above. The indications are, however, that the organic muds and silts that blanket the area, thickening rapidly Gulfward, effectively retard the entry of Gulf waters (Fisk, 1948, pl. 23).

The geologic section (Fig. 5) from Morrow in St. Landry Parish southward to Abbeville on the Vermilion River, and thence to the Gulf of Mexico, shows the gentle Gulfward slope of the thick, massive deposit of sand and gravel that constitutes the principal aquifer of the region, the gradual Gulfward increase in the salinity of the water it contains, and the vertical distribution of salty water along this profile. It also shows the clay top stratum to thicken near Vermilion Bay, so that the bay water is not interconnected with the aquifer. The continuity and thickness of the aquifer westward and northwestward from the Vermilion River are comparable to that part of the section between Milton and Abbeville, where it is 650 to 700 feet thick. Thickening of the clay top stratum to the west of the ancient meander belt is more than offset by structural downwarp of the base of the aquifer. This downwarp continues as far west as Jennings in Jefferson Davis Parish, a distance of about 30 miles.

The graveliferous aquifer in southern St. Landry Parish is bifurcate southward, the lower member consisting of medium- to fine-grained sand at the latitude of Abbeville and the upper consisting of coarse sand and gravel. The regional dip or slope of the aquifer is gently southward at a rate of about 10 feet per mile. The dip is somewhat steeper in the deeper beds.

Ground Water

Fresh ground water in the lower part of the Vermilion River basin could have entered the aquifer by three different ways. It could have entered locally, where the aquifer is exposed to recharge in water-table areas in the meander-belt system; it could have entered far to the north and west, in the basin of the Calcasieu River where the clay top stratum is not present above the graveliferous beds; or it could have entered from the east, along the channel of the Atchafalaya River, which cuts into the aquifer throughout most of its course from Simmesport in Avoyelles Parish southward to a point about 40 miles northeast of Abbeville.

It is likely that entry was chiefly from the upper basin of the Calcasieu River, which occupies the outcrop area of the aquifer in northern Beauregard, Allen, and Evangeline Parishes, and in southern Vernon and Rapides Parishes. The basis for this conclusion is the

water-level contour map for the year 1903 (Fig. 6) prepared from records compiled by Harris and Fuller (1904), which shows a pressure gradient in the aquifer southward and eastward toward the lower Vermilion River. It can be inferred from this map, which represents the approximate hydrodynamic balance of recharge and natural discharge of the aquifer for a period of thousands and perhaps tens of thousands of years, that the Vermilion River has acted as a line of escape during the recent geologic past. Because the Atchafalaya River is a very youthful stream (about 100 years old) it could not have exercised much influence on natural ground-water movements in the geologic past.

The hydraulic gradients in the aquifer have now been reversed throughout the southern and eastern parts of the rice-farming area, as a result of heavy withdrawals from wells, principally for irrigation. The Atchafalaya River is now surely providing recharge, as evidenced by the water-level contour map for September 1951 (Fig. 7), which shows a pronounced hydraulic gradient westward from the Atchafalaya Basin.

The Vermilion River, being a tidal stream for a distance of more than 40 miles inland, and thus subject to a rather narrow range of stage variation, is alternately influent and effluent. During the early spring months, when ground-water levels are at their highest, the river receives effluent seepage from the aquifer throughout the lower basin, as shown by the water-table map, Fig. 8. Profiles of the water table (Fig. 9) demonstrate even more graphically the hydraulic relation between aquifer and stream.

During the late summer and early fall, when water levels in wells decline markedly as a result of heavy withdrawals for rice irrigation, the river recharges the aquifer along at least a part of its course. The map and profiles of the water table, Figs. 10 and 11, show the nature of this seasonal reversal of flow. It should be noted that in the lower basin influent-seepage gradients in the fall are considerably steeper than the effluent-seepage gradients in the spring, especially below Abbeville, indicating that the rate of recharge from the river in the fall is more rapid than the rate of loss to it in the spring. The effect of a steady withdrawal of about 8 million gallons a day from industrial wells a few miles southeast of Abbeville is the most noticeable anomaly on the maps, but such withdrawal could never produce the regional declines of water level that induce large-scale recharge from the river throughout most of the lower basin during the summer and fall. Pumping at a rate greater than a billion gallons a day from many rice-irrigation wells tapping the aquifer to the west and northwest is largely responsible for the reversal of flow.

Because water moves a great deal more easily in the river channel than in the aquifer, the river serves to equalize the hydraulic head of water in the aquifer along its length. Both influent and effluent seepage conditions probably occur simultaneously in different reaches of the stream during the irrigating season. Thus an accurate computation of the net effect of the stream upon the aquifer would require continuous records of water level in many wells along its course. However, a lack of such detailed water-level records does not make the conclusions of this paper any less valid.

The hydraulic characteristics of the aquifer have been determined by pumping tests above and below Abbeville. Figures for transmissibility of the aquifer are available for use in flow computation when adequate water level records become available. Transmissibility has been defined as the rate of flow, in gallons a day, through a cross section of the aquifer 1 mile wide and the full saturated thickness of the aquifer under a hydraulic gradient of 1 foot per mile (Theis, 1935, p. 520). Increments of flow from or to the river, by channel segment, can be computed for weekly or monthly average gradients derived from detailed water-level records.

Salt-Water Intrusion

With this free interchange of surface and ground water in mind, let us turn to the matter of salt-water intrusion of the Vermilion River. It has been demonstrated (Hendricks, 1952) that saline water from the Vermilion Bay intrudes the river in dry years, as a result of withdrawals from the stream for rice irrigation. During the 1951 irrigating season the channel of the Vermilion River was filled with saline water as far upstream as Milton (38 miles above the mouth) for a period of about 12 weeks. For a considerably longer period the channel contained saline water in its lower reaches.

Salt-water intrusion of the aquifer occurred in 1951 as a result of this condition. The maximum rate of influent seepage occurred during and after the irrigating season, as indicated on Figs. 10 and 11. This was largely because of the regional water-level decline in the aquifer, shown on Fig. 7.

Rice farmers along the Vermilion River and the Intracoastal Waterway generally irrigate with surface water when available supplies are usable. Many of them have water wells, and when surface sources become salty they turn to their wells. Resulting water-level declines in the aquifer along the Vermilion River thus occur at a time when the salinity of water in the river is highest. Recharge from the river is therefore accelerated at the worst possible time.

Although many farmers who had no wells were forced to use saline water from the Vermilion River or the Intracoastal Waterway in 1951, a large number of them put down wells during the summer and fall. By conservative estimate, some 60 new irrigation wells were made in the lower Vermilion River area during 1951. Although many of these wells were not pumped very long in 1951, the stage is now set for heavy withdrawals in this area in future dry years.

As a result of widespread heavy withdrawal from irrigation wells the water level in the principal aquifer declined to the lowest point on record in August 1951. In the Gueydan area, about 20 miles west of Abbeville, it fell 10 feet lower than ever before. This is an indication of the intensity of ground-water withdrawals in an area generally supplied almost entirely by stream water.

That salt-water intrusion of the aquifer did occur in 1951 is evidenced by the increase in the salinity of water from wells near the river, which of course, would be expected to show the first signs of contamination. The graphs on Fig. 12 show the rate of increase in the

salinity of water in the Vermilion River at Perry and Bancker's Ferry, about 2 and 4 miles, respectively, below Abbeville, and of water from a rice-irrigation well near Perry, about 4,000 feet from the west bank of the river (Fig. 8). Similar records are available for other wells in the lower part of the basin.

It is not possible to analyze the intrusion problem by study of salinity records for water from wells that tap only the upper part of the aquifer because saline water is more dense than fresh water and goes to the bottom of the aquifer. Although the aquifer beneath the lower Vermilion River basin has a thickness of at least 500 feet, most wells tapping it are less than 250 feet deep. Thus it would be possible for salty water to partly fill the aquifer, and even to move many miles from the source of contamination, before it were evident in the discharge from wells.

Because it is more dense than fresh water, the salty water that enters the aquifer from the channel of the Vermilion River is not flushed out when ground-water levels recover and the aquifer becomes effluent. Contamination is incremental, and increases in severity with each intrusion. The salty water that enters the aquifer in this area can be removed in but one way: it must ultimately be pumped out by wells. Few rice farmers will continue to pump from wells yielding water too salty to use on their crop, and the final result of contamination will probably be the abandonment of wells as a source of supply. There will be no advantage in pumping salty water from the aquifer until the source of contamination has been removed or made ineffective.

SUMMARY AND CONCLUSIONS

Although available data do not enable estimates to be made of the rate or extent of salt-water contamination of the aquifer by the Vermilion River, there is good evidence that contamination does occur in the lower part of the basin whenever salty water intrudes the river from Vermilion Bay. Intrusion of the stream results primarily from withdrawals by rice irrigators; and at the time water is pumped from the stream for irrigation, water is also being withdrawn from the aquifer by more than a thousand wells, for the same purpose. The resulting decline of the pressure head in the aquifer below the level of water in the Vermilion River induces recharge from the river. When the water in the river is salty the aquifer is subject to contamination.

Any method of alleviating the threat of contamination should include provision for greater losses of water from the river to the aquifer in future years than at present as water levels in the aquifer decline because of increased withdrawals from wells throughout southwestern Louisiana. However, if saline water can be prevented from entering the Vermilion River, more of the river water will be used for irrigation and less pumped from wells; influent seepage of fresh water from the river would then assure local ground-water users of fresh supplies, provided wells were screened at shallow depth and pumped at low rates, to avoid coning of salty water now present in the base of the aquifer.

The importance of salt-water intrusion from the Vermilion River cannot be overemphasized. Until it is effectively prevented the ground-water resources of a large part of southwestern Louisiana are in danger of salt-water contamination.

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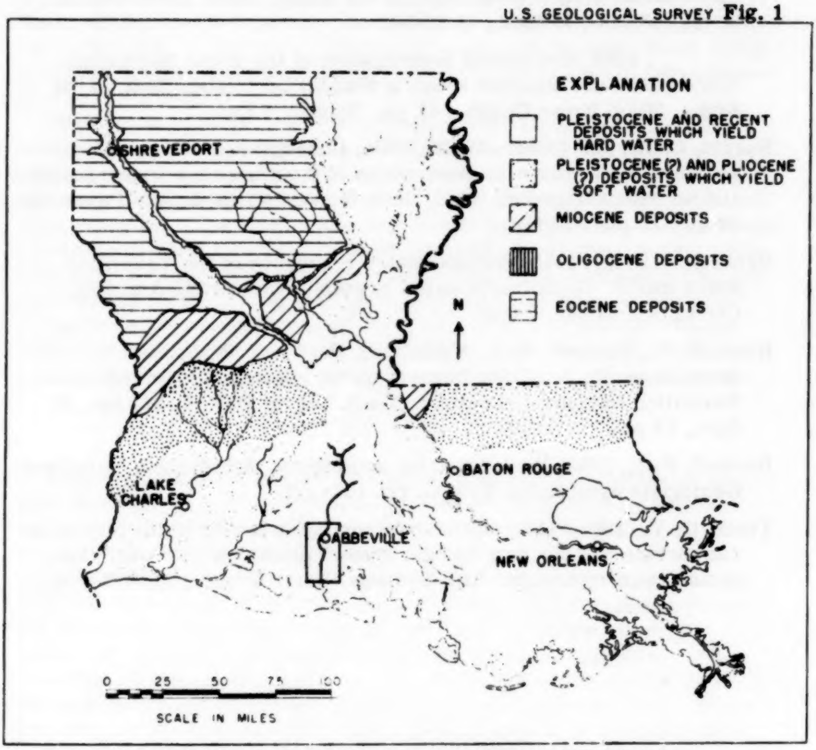
U.S. GEOLOGICAL SURVEY **Fig. 1**



A GENERALIZED GEOLOGIC MAP OF LOUISIANA SHOWING THE AREA COVERED BY THIS PAPER

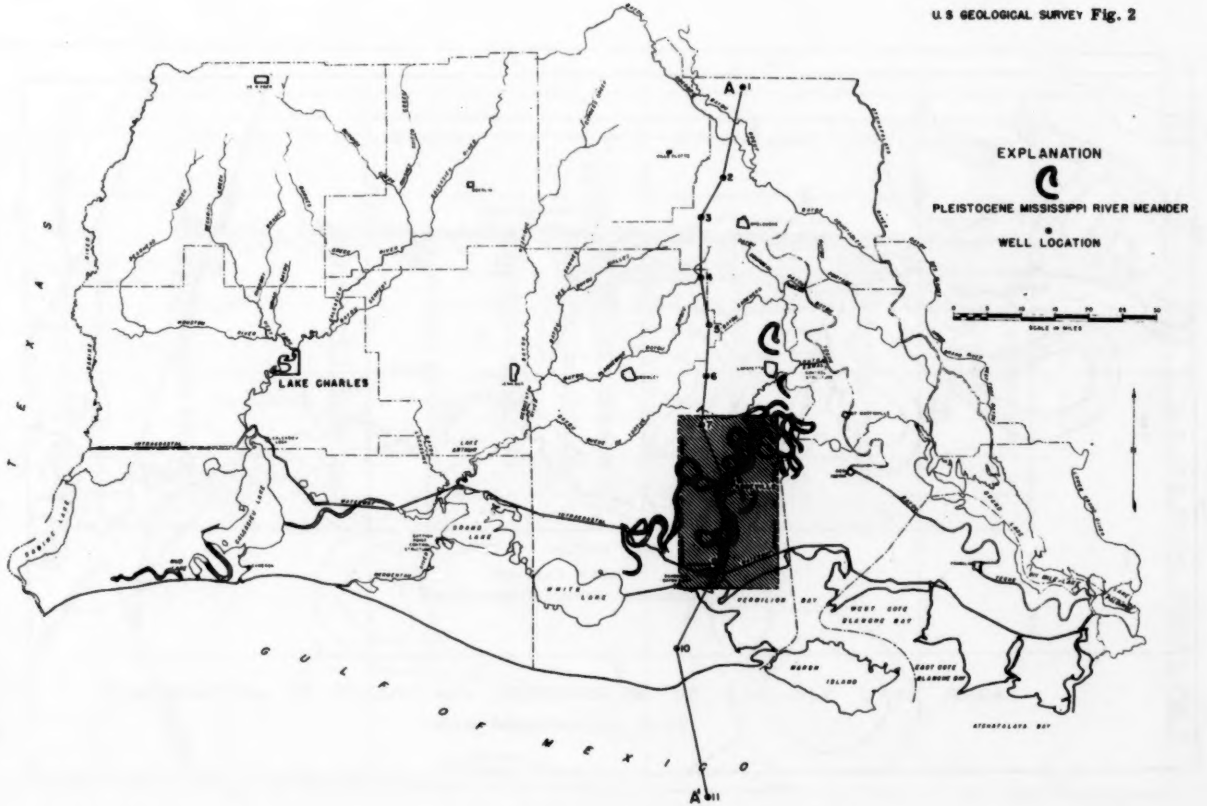
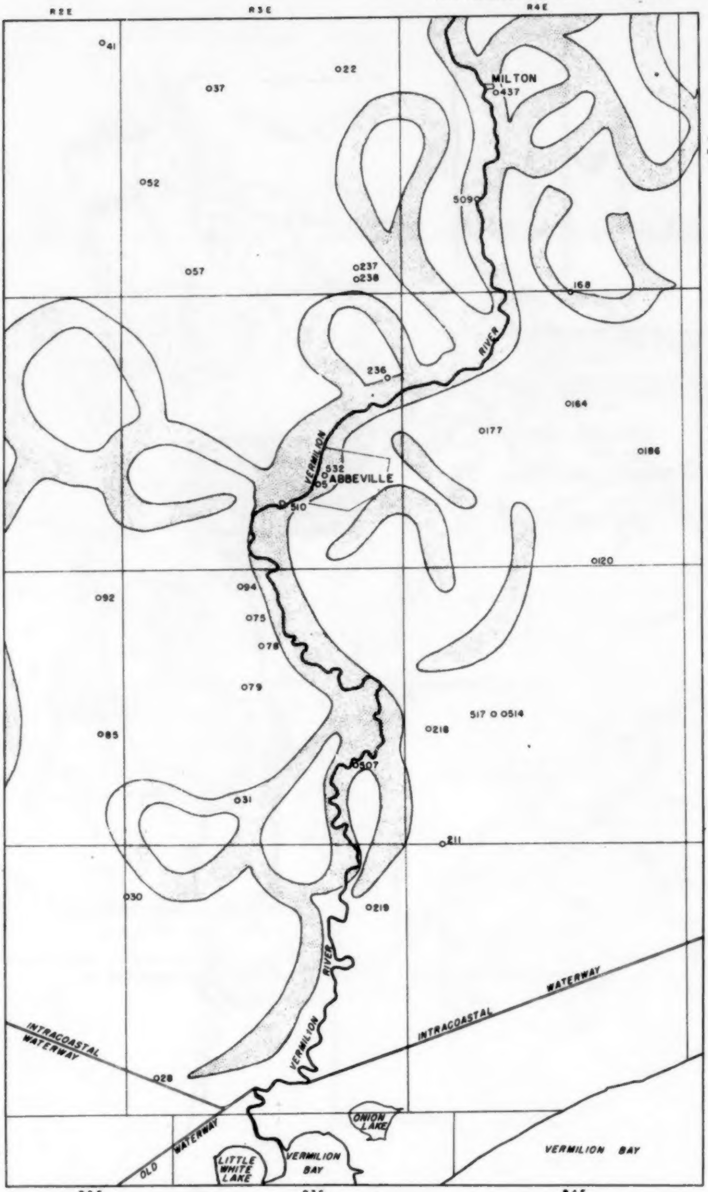
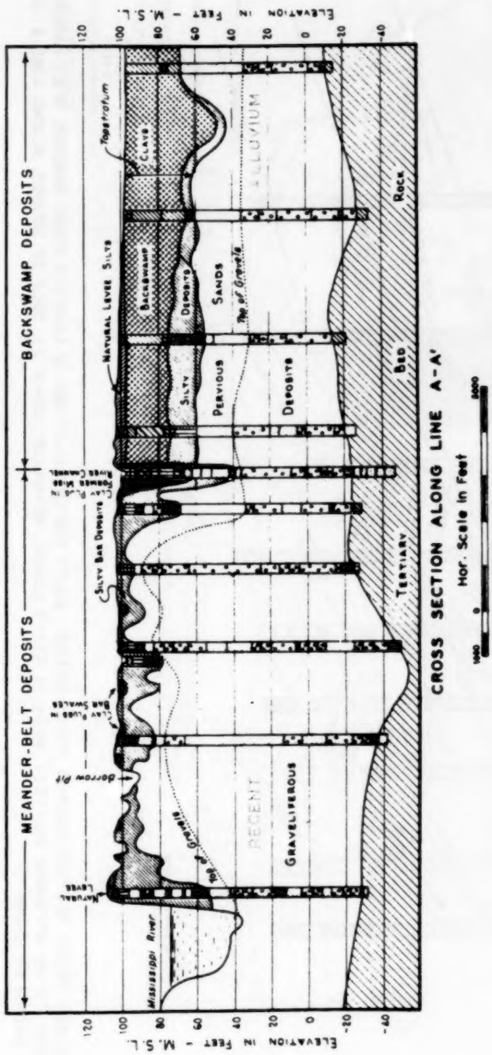


Fig. 2—Map of southwestern Louisiana showing the lower part of the Vermilion River basin at the southeastern margin of the rice-farming area, and its relation to a Pleistocene Mississippi River meander-belt system.

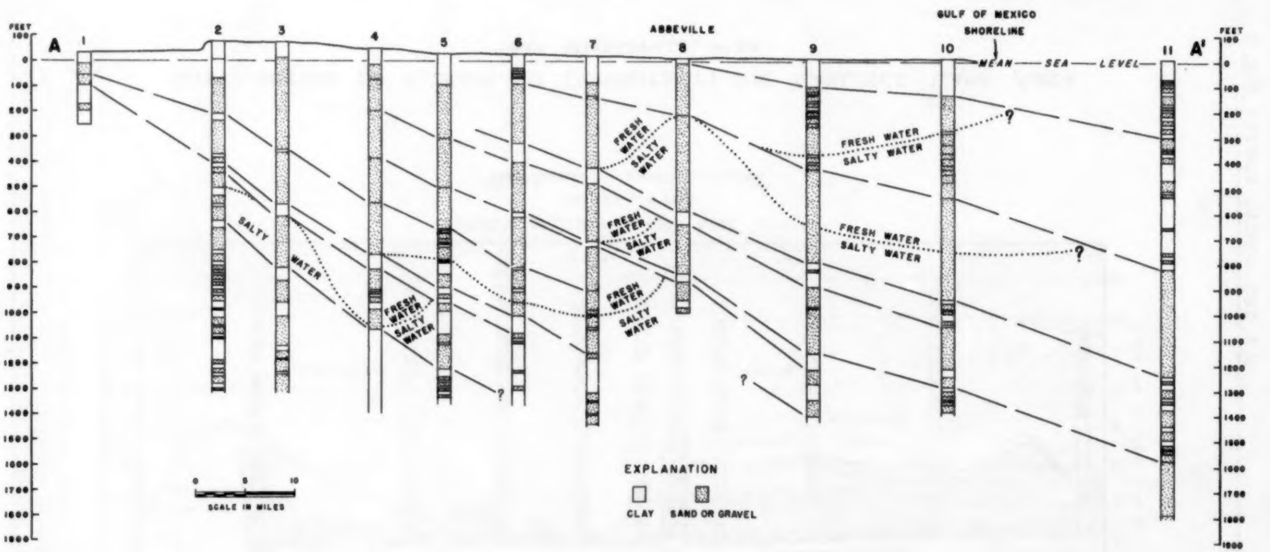


Map of the lower part of the Vermilion River basin showing the effect of the meander belt of a Pleistocene Mississippi River upon the modern course of the Vermilion River.



DISTRIBUTION OF FLOODPLAIN DEPOSITS IN THE CARLISLE LAKE AREA
NEAR MAYERSVILLE, MISS.

PROFILE OF DEPOSITS TRANSVERSE TO A MISSISSIPPI RIVER MEANDER BELT
AND ITS ADJACENT BACKSWAMP AREA (AFTER FISK)



GEOLOGIC CROSS SECTION SHOWING FRESH WATER - SALTY WATER RELATIONS IN AQUIFERS FROM MORROW, IN ST. LANDRY PARISH TO AN OFFSHORE OIL-TEST WELL IN STATE LEASE, VERMILION BLOCK 71, GULF OF MEXICO, ALONG LINE A-A' AS SHOWN ON FIGURE 2

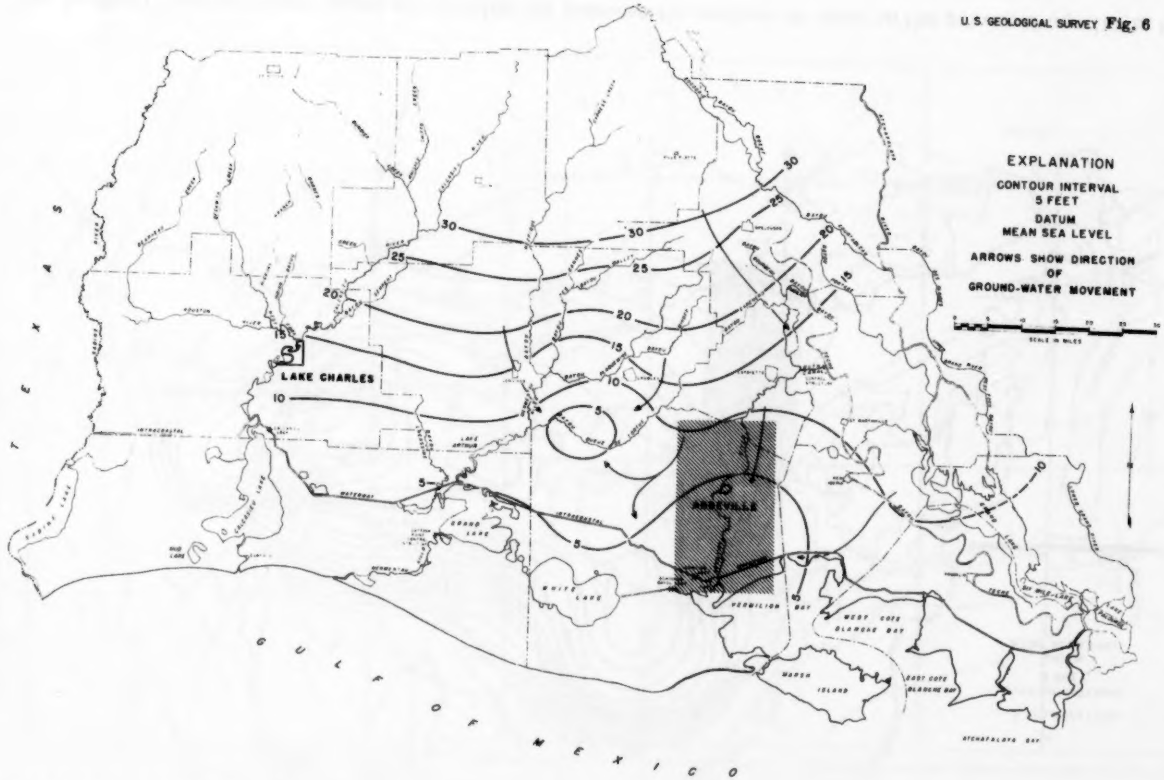


Fig. 6—Map of southwestern Louisiana showing the piezometric surface of water in the principal aquifer in 1903.

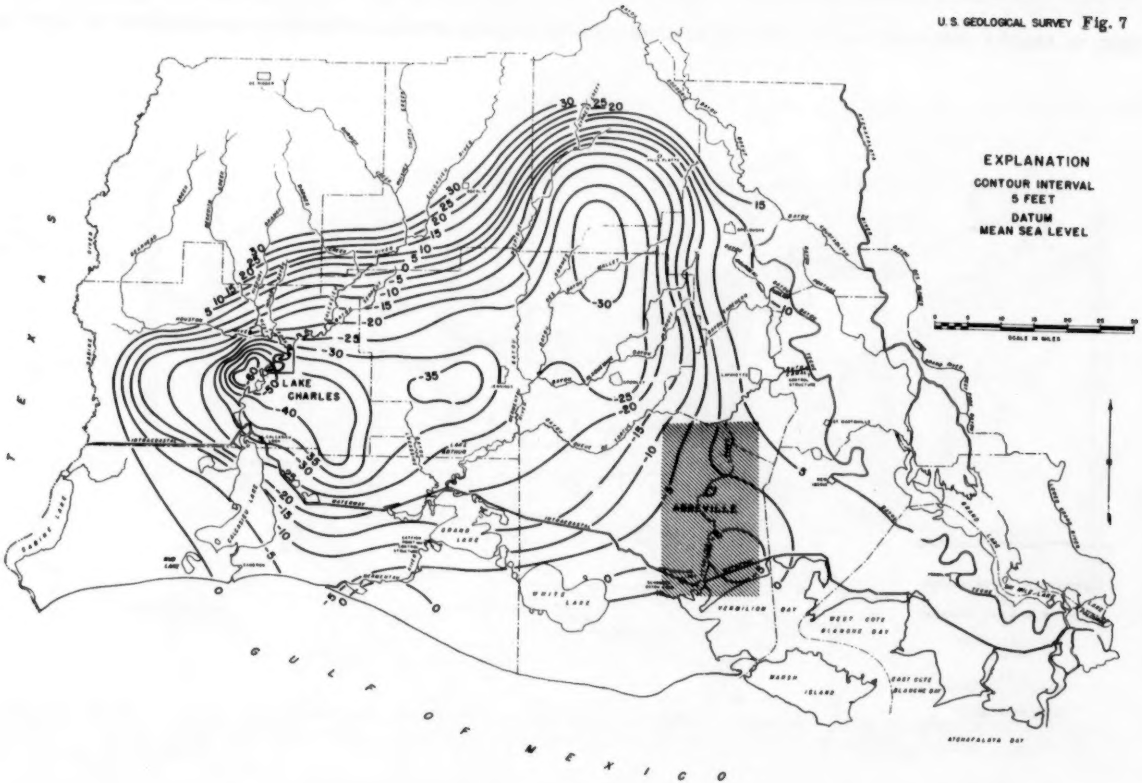
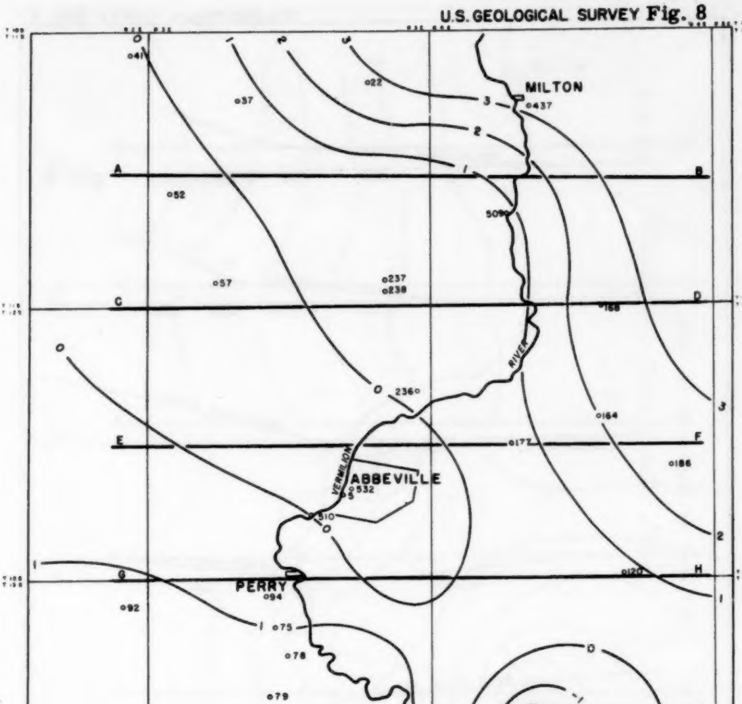
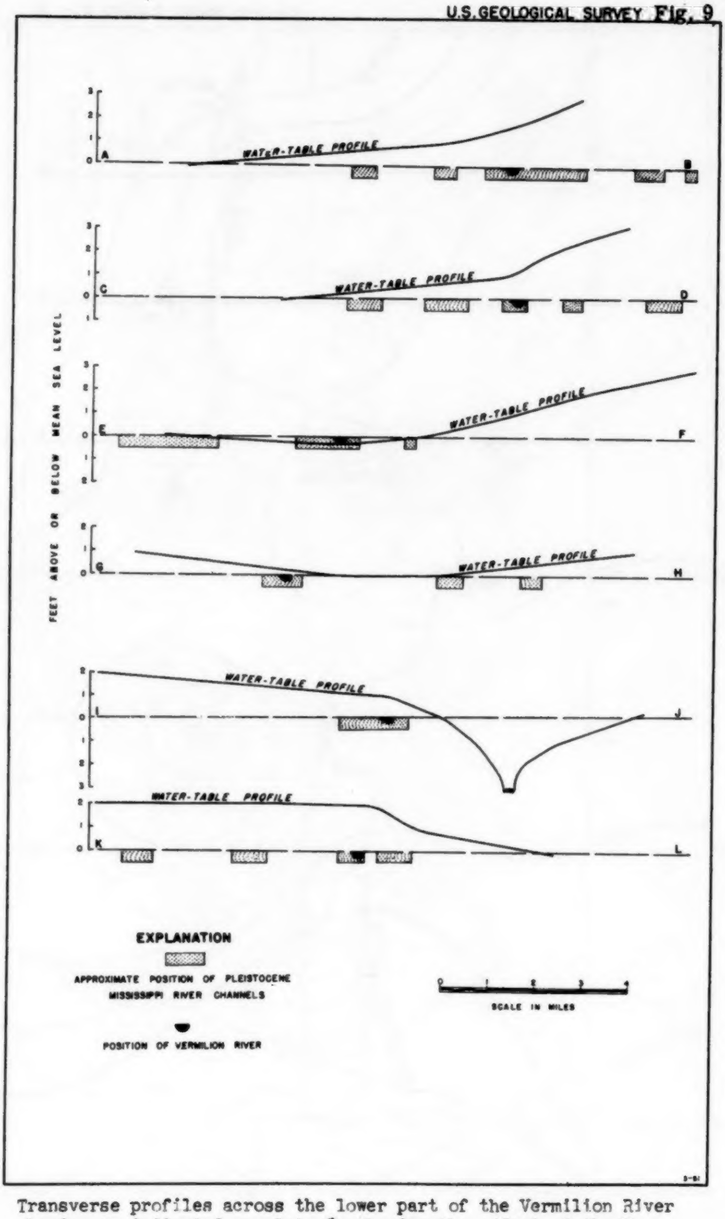


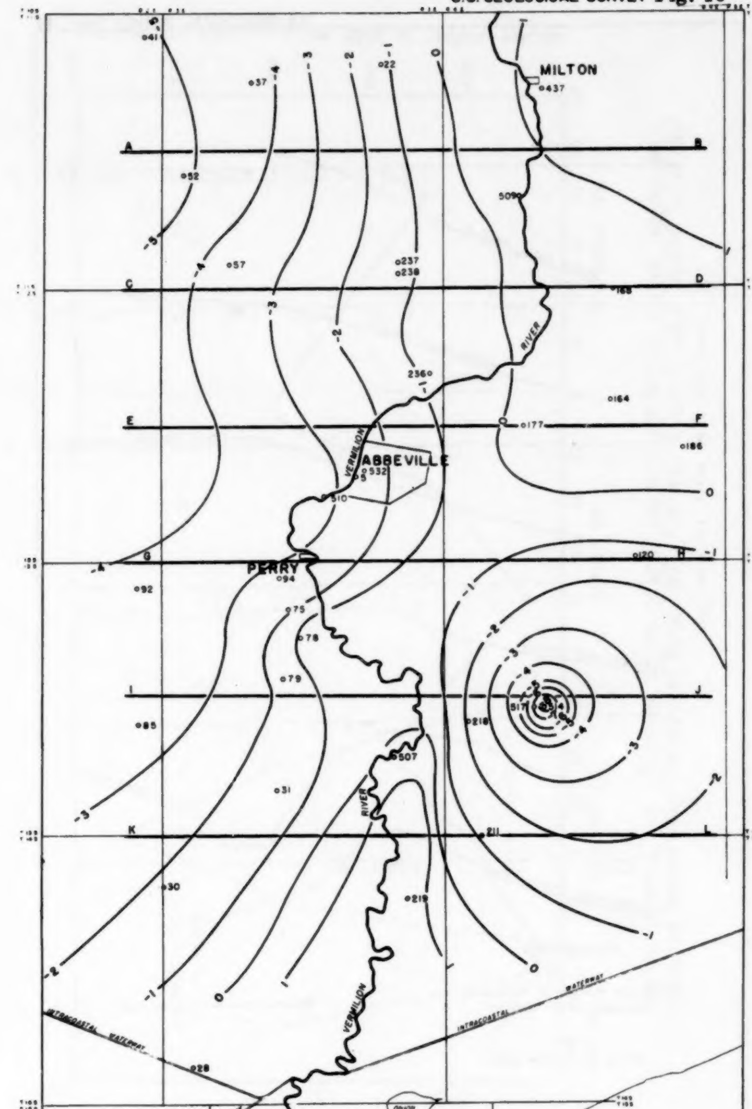
Fig. 7—Map of southwestern Louisiana showing the piezometric surface of water in the principal aquifer in September 1951.



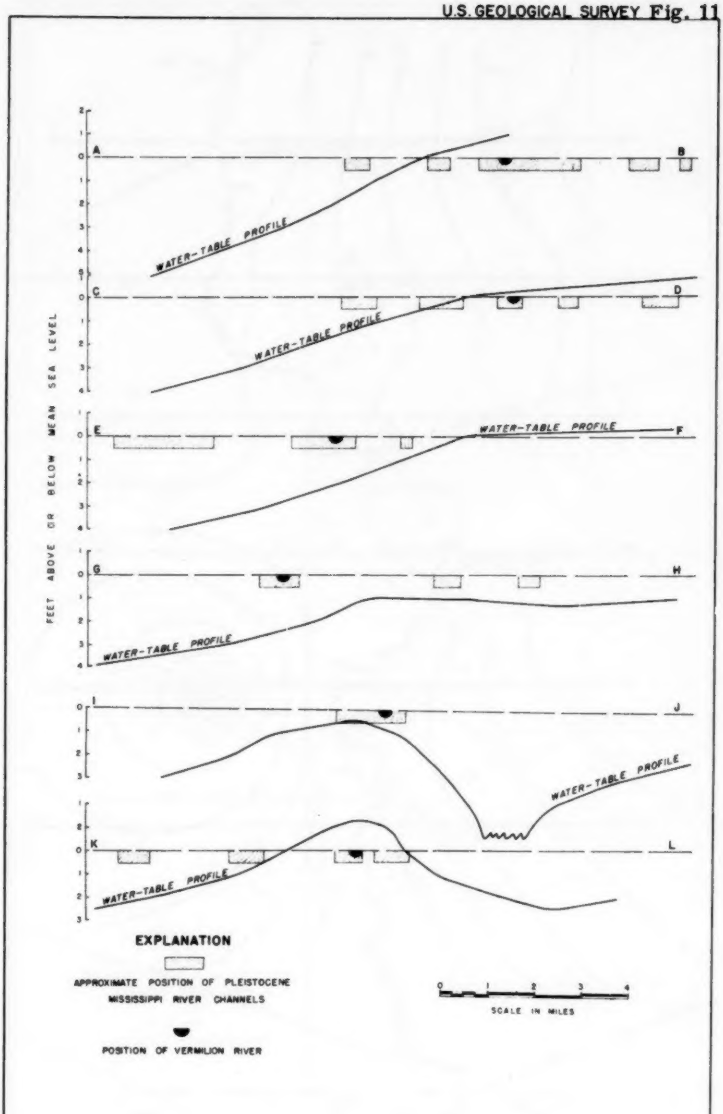
Map of the lower part of the Vermilion River basin showing the altitude of the water table in the principal aquifer in March 1951.



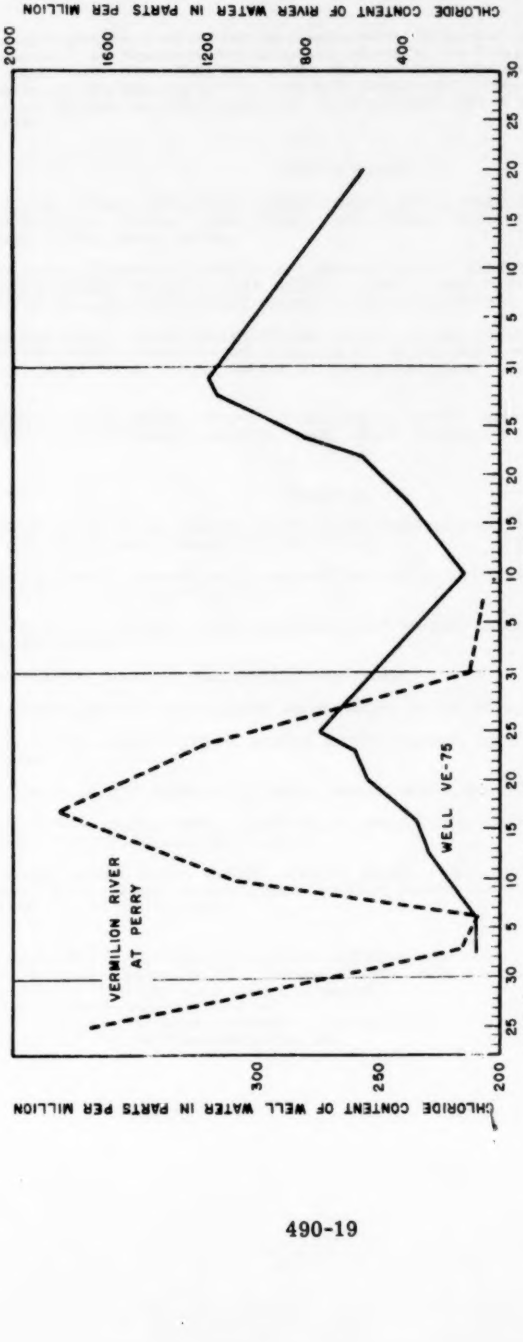
Transverse profiles across the lower part of the Vermilion River basin, as indicated on plate 8, showing the effect of the Vermilion River on the water table in the principal aquifer.



Map of the lower part of the Vermilion River basin showing the altitude of the water table in the principal aquifer in November 1951.



Transverse profiles across the lower part of the Vermilion River basin as indicated on plate 10, showing the effect of the Vermilion River on the water table in the principal aquifer.



GRAPHS SHOWING THE RELATION BETWEEN THE SALINITY OF WATER IN THE VERMILION RIVER AT PERRY AND OF WATER FROM WELL VE-75, ABOUT 1 MILE SOUTH OF PERRY

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APRIL: 428(HY)[c], 429(EM)[c], 430(ST), 431(HY), 432(HY), 433(HY), 434(ST).

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a. Presented at the New York (N.Y.) Convention of the Society in October, 1953.
b. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.
c. Discussion of several papers, grouped by Divisions.
d. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
e. Presented at the Atlantic City (N.J.) Convention in June, 1954.